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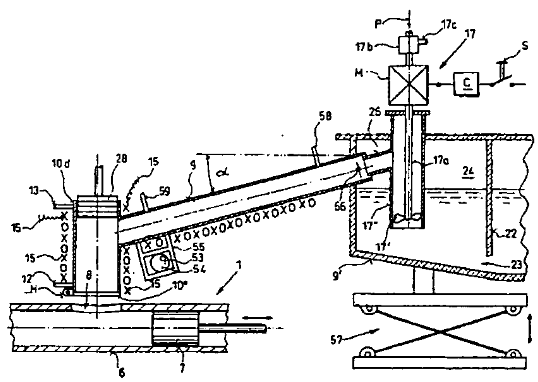
(54) PROCEDE D'OBTENTION D'UNE SUSPENSION D'ALLIAGE PARTIELLEMENT SOLIDIFIEE ET DISPOSITIFS Y RELATIFS

(54) METHOD FOR PROVIDING A PARTIALLY SOLIDIFIED ALLOY SUSPENSION AND DEVICES

(57)
The invention relates to a method for providing a partially solidified alloy suspension, wherein the alloy is initially in a liquid state and is subsequently cooled.In order to be supplied to a forming device (6-8), at least one of the following combinations of features is carried out: a) the residence time on the suspending line (9) is selected in such a way that the desired phase content is obtained at least approximately within the cycle time of the forming machine, b) at least 20 % of the fusion heat is removed from the liquid alloy on the suspension line (9), as disclosed in enthalpy values in kJ/mol, and/or c) the liquid alloy is fed upon distribution of a first plurality of nuclei in a melt volume continuous to a second additional nucleating step in a turbulent flow with heat extraction and the partially solidified alloy suspension thus obtained is conveyed to a forming device (6- 8) in a third step. A device for carrying out the method advantageously comprises a storage chamber (9') for liquid alloy and a suspending line (9) running from the input to the output arranged downstream therefrom.



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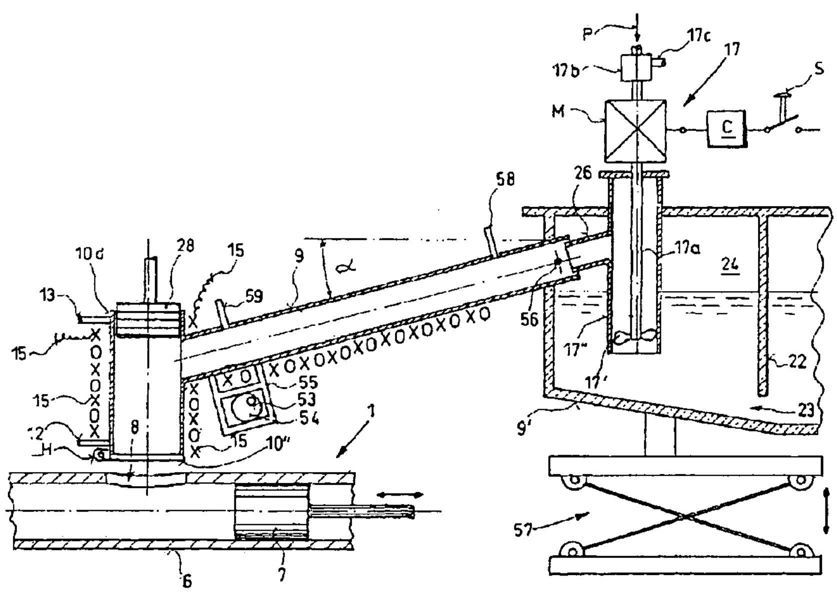

(57) Abrégé/Abstract:
The invention relates to a method for providing a partially solidified alloy suspension, wherein the alloy is initially in a liquid state and is subsequently cooled.In order to be supplied to a forming device (6-8), at least one of the following combinations of features is carried out: a) the residence time on the suspending line (9) is selected in such a way that the desired phase content is obtained at least approximately within the cycle time of the forming machine, b) at least 20 % of the fusion heat is removed from the liquid alloy on the suspension line (9), as disclosed in enthalpy values in kJ/mol, and/or c) the liquid alloy is fed upon distribution of a first plurality of nuclei in a melt volume continuous to a second additional nucleating step in a turbulent flow with heat extraction and the partially solidified alloy suspension thus obtained is conveyed to a forming device (6-8) in a third step. A device for carrying out the method advantageously comprises a storage chamber (9') for liquid alloy and a suspending line (9) running from the input to the output arranged downstream therefrom.

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Abstract

The invention relates to a method for providing a partially solidified alloy suspension, wherein the alloy is initially in a liquid state and is subsequently cooled. In order to be supplied to a forming device (6-8), at least one of the following combinations of features is carried out: a) the residence time on the suspending line (9) is selected in such a way that the desired phase content is obtained at least approximately within the cycle time of the forming machine, b) at least 20% of the fusion heat is removed from the liquid alloy on the suspension line (9), as disclosed in enthalpy values in kJ/mol, and/or c) the liquid alloy is fed upon distribution of a first plurality of nuclei in a melt volume continuous to a second additional nucleating step in a turbulent flow with heat extraction and the partially solidified alloy suspension thus obtained is conveyed to a forming device (6-8)method in a third step. A device for carrying out the method advantageously comprises a storage chamber (9') for liquid alloy and a suspending line (9) running from the input to the output arranged downstream therefrom.

METHOD FOR PROVIDING A PARTIALLY SOLIDIFIED ALLOY SUSPENSION AND DEVICES

The present invention relates to a process in accordance with the preamble of claim 1 and to the devices having the features of the preamble of claim 6.

A process of the above type is known from EP-A-0 745 694. This process uses an open casting ladle to pour out the melt above an open channel, the intention being that first nuclei for the formation of globular crystals should be formed on the channel. To enable these nuclei to multiply and grow, a number of individual crucibles are guided past the exit from the channel and filled with individual batches, the time which these crucibles require to move along a path or a carousel being used to form globules before the last crucible is then heated to facilitate pouring and is then emptied into a forming machine, such as a die-casting machine.

This known process is relatively complex and disadvantageous, firstly because a large number of individual crucibles have to be provided and moved along a path. This alone entails considerable structural outlay. However, should work be interrupted at the forming machine, the temperature in the large number of crucibles will be different than the desired temperature, leading to a different solids content, and consequently it may no longer be possible to empty out the material which has solidified in the crucibles. This then

leads to a corresponding loss of material.

US-A-3,902,544 has disclosed another process in which a furnace vessel is heated by induction coils at its periphery and the liquid metal is fed to three discharge pipes which are connected to the base wall and in which it is stirred into a thixotropic state, forming degenerated dendrites. This is relatively complex and the final effect - as has been demonstrated - is relatively ineffective. One factor in this respect is the fact that the stirring entails a high level of outlay on both design and energy and may give rise to operating shutdowns. Arranging the discharge pipes in the region of the base also leads to increased dendrite formation, since the base wall of the furnace vessel is already subject to a certain cooling and consequently a type of "sump" comprising dendritic primary crystals was formed and was fed directly to the discharge pipe in question, where the dendrite growth was then promoted by continued cooling.

Electromagnetic stirring in continuous-casting installations is also known from a very wide range of documents. This stirring has always taken place using high shear forces, since it was important to shear off and "degenerate", i.e. comminute and round off, dendrites which form at the edge. However, anyone who has ever stirred a cup of coffee will know that during stirring a dead zone is formed in the center of the stirring circle, in which no

mixing takes place. However, this leads to temperature and concentration gradients.

Therefore, the invention is based on the object of making a process of the type described in the introduction more efficient. This is achieved by the characterizing features of claim 1.

Unlike in the prior art which has been described above, the invention is based on the discovery that these previous processes have been primarily based on the object of destroying dendrites which form, but this destruction could be substantially avoided if dendrite formation were to be suppressed to a considerable degree from the outset. Consequently, moveable stirrers or parts or other stirring devices can be dispensed with.

To do this, it is necessary to consider the "mechanism" of the solidification of metal. According to the book "Metallurgie des Stranggießens" [Metallurgy of Continuous Casting] by Prof. K. Schwerdtfeger, Verlag Stahleisen GmbH, Dusseldorf, 1992, p. 59, the following sequence of events results during cooling of a melt:

1. firstly, the formation of cells,
2. which are converted into dendritic cells,
3. which then become definite dendrites before
4. any slurry-like solidification at all, with additional formation of globules, occurs.

Therefore, if the aim is to achieve a globular

microstructure, according to these details it would be impossible to get round the formation of dendrites. The explanations given below will demonstrate that this can in fact be achieved.

There will now follow an analysis of why so many dendrites in fact form from the metal which is per se in liquid form. These dendrites grow out of the cooler zone toward the warmer zone, resulting in significant shifts in concentration. Briefly, the considerations undertaken by the inventors were as follows: the profile of the concentration in front of a solidification front of this type can be determined by the diffusion equation or Fick's 2nd law. However, a boundary layer, the thickness δ_N of which is dependent on various factors, including the mixing, and which likewise has a concentration difference with respect to the melt, builds up in front of the solidification front. In the known processes this leads to considerable mixing, for example as a result of electromagnetic stirring, being set in motion in order firstly to break up this segregation area and secondly to shear off the dendrites which have already formed.

On the other hand, an area of what is known as "constitutional supercooling" only occurs in a melt when the gradient of the actual temperature is greater than or equal to the gradient, which is induced by concentration differences at the solidification front, of the liquidus

temperature (which is predetermined for a specific alloy). However, the aim, if a semi-solid material is desired, is to achieve a solidification front with a thickness of virtually zero. This then presents the question of how to achieve this.

This question then in each case led to the solution described in the characterizing clause of claim 1, which is carried out in one or other form but preferably in combination. In actual fact, the three characteristics mentioned are merely three different aspects of one and the same solution, as will emerge below with reference to the description of the drawings. Feature a) involves setting the residence time in such a way that it corresponds to the cycle time of the downstream forming machine. The forming machine may optionally be a forging machine, an extruder, a heat-rolling mill, a thixo-forming machine (with extruder), an extrusion machine, but preferably a die-casting machine or a continuous-casting device which operates with cycles (of greater or shorter length). In any event, this setting of the residence time therefore makes it possible to avoid the downstream connection of a large number of crucibles in which the operation of crystal growth is to take place in accordance with the prior art, with all the inconveniences which have been outlined above, since the desired suspension is already obtained at the end of the suspending section. Also, the invention if appropriate also allows a thixo-forming machine to be of simpler configuration, since the

extruder which is then generally provided no longer has to break up dendrites, but rather is used primarily to introduce the alloy suspension into a mold.

Feature b) describes the extent of cooling used to achieve the desired suspension. The cooling can be set by selecting the coolant or - if a flowing coolant, e.g. oil, is used - by setting the quantitative flow of this coolant per unit time. Evidently, strong cooling of this type has not hitherto been attempted and it has therefore been necessary to make do with a large number of crucibles connected downstream of a cooling channel. However, the invention has shown that this prejudice in the specialist field was unjustified.

According to feature c), the method steps which have previously been carried out involving nucleation and increasing the number of or growing the nuclei, has been advanced one station, specifically the initial nucleation into the reservoir, this being based on the discovery that precisely such initial nuclei, i.e. atom arrangements corresponding to the later crystal, are already present in a reservoir of this type (which is preferably a furnace). However, the distribution and feed generates a flow which enables nuclei of this type which are already inherently present to be guided into the desired direction and in this way moved to the suspending section, along which, by means of a turbulent flow, which if appropriate is generated by static

mixing, such a large number of crystallization nuclei are formed that there is simply no space for dendrite growth, i.e. in any event the basic idea of the invention is based on simply not allowing dendrites, which would then have to be destroyed, to form right from the outset.

Compared to the closest prior art, the characterizing features explained above provide the advantage of allowing a virtually continuous process without crucible-moving means and without the risk of such high material losses, instead of a batch process with a huge number of small batches (crucibles). However, there is also no need for the alloy suspension formed in this way to have any dimensional stability whatsoever, as has been aimed for in the prior art. It will also be understood that it is preferable if at least two of the characterizing feature groups explained above are used in combination with one another. It is then preferable to provide the features of claims 26 and/or 27, which make it particularly easy to match the metering of the melt to the cycle time. This means in any event that the alloy suspension is produced as required virtually simultaneously with the feed to the forming means (irrespective of the type of forming used, for example forging machine, die-casting machine, etc.).

The turbulent flow which is established at the suspending section on account of viscosity effects is inherently sufficient, but it is also possible to provide the

features described in claim 3. The static mixing makes it easy for the nuclei formed at the cooling surface to be homogeneously suspended in the melt. This suspending step at the same time suppresses the formation of a diffusion zone at the boundary layer between nucleus and melt and thereby avoids the prerequisite condition for dendrite growth. Therefore, there is no constitutional supercooling. It should be pointed out once again at this point that in the present context the term "nucleus" is to be understood as meaning a preformed atom arrangement which corresponds to the crystal lattice.

A further significant drawback of the prior art was the large areas of the alloy suspension which were left open to oxidation. Therefore, according to a refinement of the invention, feature E) of claim 3 and/or the features of claim 5 are provided.

A device according to the invention preferably has the features of claim 8 or one of the associated subclaims. However, a problem with the active cooling by means of a cooling system which is preferably provided (but which can also occur without the production of a partially solidified alloy suspension) is that the metal tends to "cake" onto the cooled walls. To avoid this, it is preferable to provide the features of claim 10.

Further details of the present invention will emerge on the basis of the following description of exemplary

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embodiments which are diagrammatically depicted in the drawing, in which:

Fig. 1A shows a device which has been configured in accordance with the invention for the purpose of providing a partially solidified alloy suspension, in order to give a more detailed explanation of the process according to the invention;

Fig. 1B shows a variant of the device illustrated in Fig. 1A together with a continuous-casting device as forming machine;

Fig. 2 shows an outlet pipe, which has been constructed in accordance with a second exemplary embodiment of the invention, of a melting furnace upstream of a die-casting machine with a die-casting die into which material is cast centrally;

Fig. 3 shows an outlet pipe, which has been constructed in accordance with a third exemplary embodiment of the invention, of a melting furnace upstream of part of an extrusion installation;

Figs. 4 and 5 show further alternative embodiments;

Fig. 6 shows a variant of Fig. 4 in a section on line VI-

VI from Fig. 4, while

Fig. 7 shows a section on line VII-VII from Fig. 6;

Fig. 8 shows a device which is composed of individual sections whose temperature can be controlled separately, and

Fig. 8A shows an enlarged exerpt of a detail A from Fig. 8; and

Fig. 9 shows a section on line IX-IX from Fig. 8.

Fig. 1A diagrammatically depicts part of the shot sleeve 6 of a die-casting machine 1 having an injection plunger 7. The shot sleeve 6 also in the usual way includes a filling opening 8, through which metal which is to be cast can be introduced in front of the plunger 7. An alloy is introduced via a transfer vessel 10d, which is in this case connected to the outlet pipe 9 of a metering furnace 9'. The advantage of a vessel 10d of this type is that its volume can easily be used to determine the volume of metal which is to be introduced into the filling hole 8 for a shot. For example, if appropriate a single melting furnace 9', which - as will be shown below - is advantageously formed as a metering furnace 9', can if appropriate be assigned to one

die-casting cell (which may comprise one or more die-casting machines in the immediate vicinity, e.g. in a star arrangement).

The transfer vessel 10d preferably has a discharge means, preferably in the form of a plunger 28 (although in principle it would also be possible to use an extrusion screw, but a plunger 28 is simpler), so that the metal which has collected therein can be forcibly pressed under pressure into the shot sleeve 6. Since the metal is in the partially solidified state, the pressure exerted in this way can if necessary reduce its viscosity, making it easier to introduce the metal into the shot sleeve. Moreover, the volume to be introduced can easily be determined by the volume of the transfer vessel 10d. If it is desired to change the volume, the transfer vessel 10d can advantageously be removed from the outlet pipe 9c by means of a releasable connection means (not shown in detail here) and replaced with a transfer vessel of larger or smaller volume.

The transfer vessel 10d may either simply be correspondingly insulated, in order to ensure an isothermal state of the metal which it contains after it has acquired a desired partially solidified state over the suspending section 9, or expediently it may also have at least one cooling means having an inlet 12, for example arranged at the bottom, and an outlet 13 and cooling pipes O. The mouth of the transfer vessel 10d may be provided with a closure means

10'' which can be slid out of the opening position shown into a closed position perpendicular to the direction running in the plane of the drawing or can be pivoted about a hinge H, as is known in the case of a tundish. A further particular purpose of the transfer vessel 10d is to match the residence time to the cycle time of the downstream forming machine 1.

However, it may arise that operating faults occur, preventing the transfer vessel 10d from being emptied immediately. In this case, there would be a risk of the transfer vessel 10d ultimately only containing completely solidified metal. To prevent this, it is preferable if the transfer vessel 10d is also provided with heater coils X. These heater coils X may be assigned a heat sensor (or a sensor, for example an inductive sensor, for detecting the state of aggregation of the metal therein, as has already been described in the literature), in order for the heater coils, if appropriate only in part, to be switched on when the metal which has cooled to the desired partially solidified state is to be kept in this state. Indeed, heater coils X of this type can also be used to enable the partially solidified material to be discharged from the transfer vessel 10d more easily by liquefying its edge zones.

The metering furnace 9' has a forced-delivery pump 17. In the process according to the invention, this pump performs a number of functions simultaneously: firstly, melt is introduced, at least periodically continuously, into the

outlet pipe 9, which forms a suspending section for the melt flowing out. In this context, it should be mentioned that it would per se also be possible to provide an open channel instead of the outlet pipe 9, but a closed pipe offers better protection against oxidation and also enables a shielding gas atmosphere to build up therein. Since the metal in the melting furnace is held in the liquid state, i.e. above the liquidus temperature, it is necessary to have a cooling intermediate step if it is desired to feed the shot sleeve 6 with partially solidified metal. It will therefore be understood that it is preferable if the metal in the melting furnace, by the outlet pipe 9, is only brought to a temperature which is no more than 30°C, preferably no more than 20°C, e.g. is only approximately 10°C, above the liquidus temperature, in order in this way firstly to save energy and secondly to accelerate the operation of cooling to the partially solidified state. The furnace 9′ is preferably provided with a metering chamber 24 which, apart from a connecting opening 23, is split by a partition 22, is connected via the connecting opening 23 to a chamber positioned in front of it, for example a chamber which is at a higher temperature, and on the exit side is directly connected to the outlet pipe 9.

A further function of the pump 17 is to generate a flow in the melt in the furnace 9′, so that unmelted crystallization nuclei, whether these be external nuclei or

small dendrites which have formed on the furnace walls, are passed into the pump pipe 17''. A propeller 17' (or a screw) acts as a distributor (mixer) and divider, so that further nuclei are formed therefrom. In this context, reference is made to Friedrich Ostermann, "Anwendungstechnologie Aluminium" [Technical Applications for Aluminum], Springer-Verlag, 1999, p. 306, which describes the advantage of stirring operations with a grain-refining action. A further function of the pump 17 is that it can be used to carry out precision metering (alloy suspension "on request") when it is assigned at least one drive, whether as transmission or as motor M, which can be switched on and off, by means of a switch S which can be actuated by hand or by a program control, for conveying purposes over the cycle time of the die-casting machine (1 in Fig. 1B). Preferably or as an alternative, the screw or propeller pump 17 is assigned a variable-speed drive M, for which purpose a motor control stage C may be provided.

To obtain additional primary nuclei, it may be expedient for at least parts of the pump 17 to be cooled. By way of example, the pipe 17'' may be provided with a cooling jacket. However, it is preferable if moving parts of the pump 17 are provided with a cooling means of this type. For this purpose, the shaft 17a of the pump 17 is formed as a hollow shaft, as is known, for example, for stirrer mills for cooling purposes, and consequently the details of a cooling

arrangement of this type do not need to be described. Accordingly, coolant runs in in the direction indicated by an arrow P through the central hollow part of the shaft 17a (a pipe which is inserted into the shaft 17a, rotates with it and, by way of example, does not extend all the way to the bottom of the cavity in the shaft 17a), then at the bottom end of this hollow part flows radially outward into an annular passage and leaves the hollow shaft 17a through a stationary rotation outlet 17b, which is known per se for stirrer mills, with an outlet collection piece 17c. However, if desired it is also possible for the propeller 17′ or the pump screw to be cooled in a manner which is known per se.

The rotation of the shaft 17a means that any primary dendrites which form at the shaft are thrown off radially into the melt and degenerate in the melt as has been described in connection with the abovementioned prior art. The advantage of the process according to the invention over EP-A-0 745 694 resides in the fact that the nucleation process is advanced in terms of both time and location, and consequently it is unnecessary for a large number of moving crucibles to be connected downstream for the subsequent cooling and nucleus growth, and there is therefore also no need for the equipment used to move these crucibles. Then, in a second step, the nucleated volume which has been preformed in this way is increased in size in such a manner that even irrespective of the effects of the static mixing, the

geometric boundary conditions also no longer allow dendrites to grow.

Therefore, the pump 17 conveys the melt into a pipe connection piece 26 which branches off from the pump pipe 17'' and to which the outlet pipe 9 is connected. The outlet pipe 9 is internally smooth but, in a similar way to the transfer vessel 10d, has cooling coils O and heater coils X for the same purpose as has been described above in connection with the vessel 10d. The melt which has been provided with primary nuclei is therefore conveyed by the pump 17, preferably in a thin film, over the base of the outlet pipe 9. The cooling means O ensures that the layer of the melt which is closest to the base becomes more viscous and starts to flow more slowly, while a hotter layer above it runs more quickly. However, the hotter layer melts the thin film below it again, so that the ultimate result is turbulence in the flow, producing a mixing effect. This mixing effect in turn homogenizes the alloy suspension which forms in this way, i.e. temperature and concentration differences over the volume of the alloy transversely with respect to the direction of flow are avoided and therefore so is the tendency for dendrites to form. Rather, further nuclei are formed, no longer allowing space for dendrites to grow, and therefore increase in size in globular form, which is of course desirable. Therefore, the desired alloy suspension is already present in substantially finished form at the exit

from the suspending section formed by the outlet pipe 9 and there is therefore no longer any need for any further crucibles.

Now, if the same alloy always with substantially the same solids content is to be used in each instance, the configuration of the arrangement shown in Fig. 1A which has been described above is sufficient. However, if it is to be possible to make changes to the alloy and/or the solids content, a problem is that given a constant inclination α of the suspending section 8 with respect to a horizontal plane shown by dot-dashed lines, the viscosity of the alloy in question will vary, which would then affect the cooling time in the outlet pipe. To obtain a melt residence time in the suspending section 9 which can be selected independently and in this way to control the proportion of the melt heat which is extracted from the melt, the angle of inclination α of the suspending section is preferably adjustable. This allows the residence time to be controlled in such a way that firstly it can be matched to the cycle time of the downstream forming machine, for example the die-casting machine indicated using parts 6-8 in Fig. 1A, and that secondly the extraction of the melt heat can if appropriate be set in this way, while a further method of setting this extraction resides in selecting the coolant which flows through the pipes O and its throughput per unit time. For example, a proportion of 20% to 60%, preferably 30% to 50%, of the melt heat can be withdrawn

from the melt as it passes along the suspending section 9, in such a manner that the desired alloy suspension is present in finished form at the lower end of the suspending section. It will be understood that the angle of inclination α will deviate from 90°, i.e. from the vertical, and will be less than 90°.

To enable the angle of inclination α to be set, there may be an adjuster device in the form of an eccentric 54, which can rotate about a stationary axis 53 or shaft, inside a frame 55 connected to the outlet pipe 9, so that the pipe 9 can be inclined to a greater or lesser extent. At the other end, the pipe can be pivoted about an axis 58 which is located preferably close to a wall of the furnace 9′ or close to the pipe connection piece 26. It will be understood that the embodiment shown merely represents an example and that it may even be preferable to use a fluidic adjustment system, a rack system or a lever transmission in order to achieve greater adjustment movements, for example to raise the suspending section 9 above the horizontal plane shown by the dot-dashed line, in order in this way to enable the alloy to flow back into the furnace 9′ should faults occur at the forming machine.

In order to as far as possible avoid a skew position of the transfer vessel 10d, the furnace 9′ preferably stands on a lifting frame, which is only diagrammatically indicated and may be formed in a conventional way, for example as a

frame which can be raised and lowered hydraulically or mechanically. It is preferable for the adjustment of the adjuster means 53-55 or the rotation of the shaft 53 to be synchronized with the movement of the lifting frame 57. Of course, it would theoretically also be possible for the furnace 9' to be provided at such a high level that the vessel 10d is under all circumstances above the filling opening 8 (which is then of correspondingly large dimensions) even if the inclination of the pipe 9 varies.

The cooling means 0 was mentioned above. However, cooling may additionally or alternatively also take place in such a way that shielding gas, e.g. nitrogen, is fed into the outlet pipe 8 via an inlet 58 and is discharged via an outlet 59 at the end. In such a case, there is no need to heat the gas, which can be supplied at room temperature, i.e. approximately 20°C, or even in liquid form. This is particularly advantageous when processing magnesium, in which case the interior of the furnace 9' will also be filled with an inert atmosphere of this type. Of course, a measure of this type is also advantageous for aluminum or any other metal, since it greatly reduces or virtually eliminates oxidation.

According to Fig. 1B, the metal which is to be cast arrives from the metering furnace 9' (Fig. 1A), of which only the outlet pipe 9 is shown in Fig. 1B. In the embodiment shown in Fig. 1B, the step of filling a forming machine 1a is

carried out using a transfer vessel 10 which is separate from the outlet pipe. The advantage of a separate transfer vessel 10 resides, inter alia, in the fact that it is simply no longer necessary to assign each forming machine a dedicated melting furnace with outlet pipe 9, but rather it is possible for a single melting furnace to be positioned at a central location, from which the individual forming machines can be supplied via vessels 10 of this type.

A continuous-casting means 1a of a form which is known per se, as the forming machine, is connected downstream of a collection vessel or tundish 10e, beneath the transfer vessel 10. This is a similar continuous-casting means to the one which has been disclosed by DE-A-1 783 060, the only difference being that in this continuous-casting machine it was necessary to provide an electromagnetic stirring means in order to destroy dendrites. This means can now be eliminated by the invention, so that the continuous-casting device 1a can be of simpler and less expensive construction. It should be noted that a continuous-casting machine 1a of this type can be operated either cyclically - to produce billets of greater or lesser length - or continuously. It should be noted that the combination of a continuous-casting device 1a with a metering furnace 9′ which includes a pump 17, as described in detail below with reference to Fig. 4, is particularly advantageous because a continuous-casting installation and the quality which it achieves are by no

means least also dependent on as far as possible achieving a uniform static liquid pressure. By way of example, it is known from US-A-4,358,416 or EP-A-0 095 596 to provide a means for controlling the level in the tundish. However, if the metering pump 17 is combined with the continuous-casting means, a constant static liquid pressure is automatically obtained, and under certain circumstances it is even possible to dispense with the tundish 10e, enabling the metering pump 17 to supply the continuous-casting device 1a directly.

To make the mixing effect described above more intensive, the vessel 10 now has a static mixing means, preferably in the form of wall protrusions 11 which mesh with one another, in each case turn the metal from one side to the other and thereby mix the metal. These wall protrusions therefore mix the metal while it is being introduced and while it is flowing out. Unlike in the known batch process, in which individual batches are introduced into a large number of crucibles, for example moving along a carousel, in this case, therefore, a throughflow process is employed or the partially solidified metal is obtained in a through-flow process, in which the closure 10'' is always open or may even be omitted altogether. At the same time, the vessel 10, in a similar manner to the vessel 10d which has been described with reference to Fig. 1a, may either simply be correspondingly insulated, in order to keep the alloy suspension which has been introduced isothermal, or

alternatively it may, like the vessel 10d, expediently have at least one cooling means with an inlet 12, for example arranged at the bottom, and an outlet 13, as well as cooling pipes O in the interior of the protrusions 11. This ensures the transition from the (still) liquid state, as it flows out of the pipe 9, into a cooled state; the mouth 10′ of the vessel 10 may once again be provided with a slideable closure 10′′, but in the present case will not be, as has been mentioned above. It will be understood that when a portable transfer vessel 10 of this type is used, the cooling capacity of the outlet pipe can at least be reduced, for example the cooling means O can be dispensed with and it is possible to make do with cooling by shielding gas alone. For the same reason as has been described above with reference to the vessel 10d, it is also preferable to provide a heater means X which can be switched on as desired and can also be used to melt solidified material, so that there is no need for any separate shock heating 16a.

It will be explained below with reference to Fig. 8 how zoned monitoring of the temperature with corresponding control can be achieved. However, in the embodiment shown in Fig. 1B, it may be expedient for the vessel 10 (or the vessel 10d) to be divided, for example along its longitudinal axis 14, and to be dismantlable, so that it can be cleaned if necessary. In such a case, it will be expedient if each half is assigned a dedicated feed and discharge for the

corresponding temperature-control medium (cooling or heating medium), as is shown in the case of the four connections 15 (in each case one pair for each half of the vessel) for the electrical connections of the heater coils X.

Fig. 2 diagrammatically depicts the die-casting machine 1 having a plurality of die parts 2, a fixed platen 3 for a stationary die part 4, and a stationary shield 5. The shot sleeve 6, in which the injection plunger 7 can be moved along the length, is clamped in between the platen 3 and the shield 5. The shot sleeve 6 may be provided with a heater means 16. It will be understood that as an alternative to the die-casting machine 1 it is also possible to use any other forming machine, for example an extruder on its own or as a thixo-forming machine, for example in accordance with WO 97/21509. However, while the extruder in that document has the function, inter alia, of destroying any dendrites by means of its shear forces (and therefore also has a correspondingly high demand for energy), this is not the case of the present invention, since in this case no dendrites are formed.

In the present exemplary embodiment, mixing protrusions 11a of a gravity mixer or static mixer are integrated in the outlet pipe 9a of the melting furnace 9', which latter is only partially illustrated. It should be noted at the present point that although it is preferable for the mixing to be carried out under the force of gravity, it

would also be conceivable for the mixing protrusions, e.g. 11a, to be accommodated in a rising cooling pipe through which the metal is conveyed, for example by means of gas pressure. If appropriate, the melting furnace 9′ may be displaceable, in order to be able to reach each forming machine which is to be supplied, i.e. it does not need to be assigned in a stationary position to the forming machine. In this case, as in the following exemplary embodiments and in the same way as in Fig. 1B, however, the reference symbols are if appropriate provided with a suffix.

Therefore, if liquid metal, preferably at just above the liquidus temperature, is conveyed out of the furnace 9′ with the aid of a metering pump 17 into the outlet pipe 9a, it runs downward over the staircase formed by the protrusions 11a, the outlet pipe 9a either having a sufficient length for natural, unforced cooling to occur or once again - as illustrated - being provided with cooling pipes O in the protrusions 11a, which is preferable. The desired mixing effect results from the constantly recurring, cascade-like pouring onto in each case the next step 11a down.

Should the outlet pipe be so thin that the flowing metal fills its entire internal diameter, it is also possible for mixing protrusions 11a of this type to be provided at the upper or side walls of the outlet pipe, in which case the shape of the protrusions may be identical or different, but in any case different shapes, for example of the type still

to be shown below, may be present in mixed form. For example, it would be conceivable for a disk provided with openings to be provided transversely across the diameter of the pipe at the upper end of the outlet pipe 9a in order to achieve a static mixing effect, so that the flow of liquid metal is divided into a plurality of partial streams which are combined again and thereby mixed downstream of the disk. However, a disk of this type constitutes a certain flow resistance, and consequently it should only be arranged at the upper region of the outlet pipe 9a.

As with the vessel 10 shown in Fig. 1B, in this case too it may be advantageous to incorporate heater coils X, in order to prevent metal from "caking" on the walls of the outlet pipe 9a should a prolonged residence time of the metal in the outlet pipe result, for example on account of operating faults. Therefore, it is particularly advantageous to use non-wetting materials for the static mixer and/or the outlet pipe 9, 9a of the furnace. Examples which may be mentioned include ceramic-coated metal or completely ceramic components. In this case, a metal plate 19 of this type is indicated by dashed lines at 19. The mixing protrusions 11a may then be arranged on the plate 19, which in Fig. 2 can be pulled out of the pipe 9a for repair or cleaning purposes. Additional strong heater coils X' may be advantageous for shock-type heating if the suspension has completely solidified, for example on account of a fault, and needs to

be made to flow again.

Furthermore, it may be advantageous to fit a high-frequency means, preferably an ultrasonic-frequency means 16a to the suspending section 9a, in order to prevent melt from penetrating into the pores of the ceramic material which forms the protrusions 11a. Particularly when ultrasonic vibrations are imposed, it has been found that such vibrations force the metal out of the pores and thereby extend the service life of the ceramic parts.

If appropriate, the lower end of the outlet pipe 9a may also be provided with a similar closure to that indicated at 10'' for the transfer vessel in Fig. 1A or B. For this purpose, it is possible to provide a slide housing 18. This makes it possible to prevent alloy suspension from flowing out in the event of faults at the forming machine (and therefore a change in the cycle time). However, if appropriate the outlet pipe 9 can be pivoted about the axis 56 (Fig. 1A), in such a manner that in such a case it is pivoted upward above the horizontal plane shown by dot-dashed lines in Fig. 1A and as a result the alloy suspension flows back into the furnace 9' (or into another storage vessel). Of course, it would also be conceivable for the outlet pipe 9a, as in the case of the vessel 10 shown in Fig. 1B, to be composed of two dismantlable halves, for example along its longitudinal axis L, so that maintenance work can be carried out more easily.

Where the text above referred to the provision of an ultrasonic means, it should be noted at this point that the use of ultrasound, for example in a vessel 10, has also been found by the inventors to have a positive effect on the microstructure of the metal. It becomes finer and the crystals become rounder. An ultrasound effect of this type can also be applied, for example, to the forming machine, such as a die-casting machine, since it then exerts a type of "vibrator effect" in a similar manner to the compacting action of concrete vibrators. Since ultrasonic vibration of this type generally propagates to all sides, it may be sufficient to fit a single ultrasound means at one location and to operate this means with an energy which is such that it has a favorable effect both on the ceramic lining of the suspending section and on the forming machine. By way of example, the ultrasound means could be arranged at a shot sleeve - which is expediently also lined with ceramic - of a die-casting machine, in which case the sound has its effects both as far as the upstream suspending section and also as far as the vessel 10, in one direction, and as far as into the cavity of the casting die. However, this means that a relatively high level of energy is required, and consequently it will be preferable to provide a plurality of ultrasound means of this type. Although an ultrasound means is preferable, it is also conceivable to use other high-frequency vibration-exciting means, such as for example an

alternating electromagnetic field, which may be effective at lower frequencies but is preferably operated at high frequency. It will be understood that this application of vibrational energy also constitutes an independent invention on its own, irrespective of the other features.

Fig. 3 shows a similar illustration to Fig. 2, but of a modified exemplary embodiment. In this case, the forming machine provided may be an extrusion press with an extrusion plunger 7b, but it may also be a shot sleeve 6a similar to the shot sleeve 6 shown in Fig. 1A for a die-casting machine. The form of this shot sleeve 6a now corresponds to a shot sleeve as described in German Laid-Open Specification 100 47 735, the content of which is hereby incorporated by reference. Specifically, it is appropriate for the shot sleeve 6a to be heated, for example, by means of heater coils 16 in order not to change the alloy suspension. In this context, it may be advantageous for the front part of the shot sleeve 6a to a certain extent to be formed as a "transfer vessel" and provided with a, for example likewise heated, sliding closure 10''.

As in Fig. 2, in Fig. 3 the outlet pipe 9b itself is likewise provided with a static gravity mixer along a meandering center line L′ between protrusions 11b which overlap one another, in a similar manner to that shown in connection with the mixer illustrated in Fig. 1B, allowing particularly intimate mixing and homogenization. Although the

static mixer may in principle be formed with internals provided with openings, in the manner of the type used for bulk materials, so that part of the stream flows outward or inward through the openings while another partial stream moves past them, in the context of the present invention protrusions which overlap one another are particularly preferred for a number of reasons. Firstly, internals provided with openings, like the abovementioned disk inserted transversely, tend to become blocked, specifically as soon as the temperature of the metal has dropped to a corresponding degree and the metal has become more viscous. Secondly, an overlap means that some of the metal flows along the wall but some of it drops onto the next overlapping protrusion 11b and from there is discharged downward, where it is combined with the metal flowing along the wall and therefore over a different path, with a mixing effect.

It has already been mentioned above that it may be advantageous to provide both cooling and heating means. Since the metal emerges from the furnace 9′ at a relatively high temperature, it may be that further heating in the event of a shutdown or interruption in operation is less necessary in the upper part of the gravity mixer. This case is shown in Fig. 3, in which only cooling coils O are provided in the upper part of the outlet pipe 9b, but, in a zonal manner, an increasing number of electric heater units X are provided the closer the mixer space 21 comes along the line L′ to the

mouth 10'b or the slide housing 18 of the outlet pipe. The shock heating 16a for emergencies, which has been explained with reference to Fig. 2, can likewise be provided.

Although the cooling means or heat-conducting pipes may per se be formed in various ways, for example may also operate with evaporable coolant, with such strong cooling there is a risk of local supercooling, which may then lead to the "constitutional supercooling" which has been described in the literature and to dendrites being formed. Therefore, cooling by means of a flowing cooling medium is preferred, in which case, although it is possible to carry out cooling in countercurrent to the flow of the metal, in the manner which has been shown with reference to Fig. 1B, it is preferable to reverse the arrangement shown in Fig. 1B, with the cooling inlet 12 at the top and the outlet 13 at the bottom, i.e. a co-current cooling arrangement, since in this way the upper region, where the liquid metal enters, is cooled to a greater extent than the lower region. Although this nevertheless overall leads to an approximately linear drop in the metal temperature over the length of the path, e.g. along the line L', in practice there tends to be a more or less gentle degression in the cooling capacity.

It has been mentioned above that the metal which emerges from the mouth 10' (or 10'a or 10'b) may if appropriate also be in semi-liquid form, i.e. may have a solids content of below 50%. Of course, this makes it easier

for the cooled metal to flow out, although in certain cases metal with a solids content of ≥ 50% by weight is preferred in particular for forming machines, such as 1 or 1a. In this case, however, it may under certain circumstances be more difficult for the metal to be introduced into the forming machine. Fig. 4 shows a way round this problem.

Fig. 4 once again illustrates the furnace 9' with the metering chamber 24, which is divided by the partition 22 apart from a connecting opening 23 and is directly connected to the outlet pipe 9c. For this purpose, the pipe 17'' of the pump 17 is immersed below a liquid level, defined for example by a sensor 25, of the melting furnace 9' and conveys the melt via the pipe connection piece 26 which projects into the outlet pipe 9c into said pipe 9c. At the location of a sensor 25 which controls the pump 17, it is also possible to provide an overflow edge which determines the liquid level without any control outlay. By way of example, the inner, lower edge of the connection piece 26 can be used as an overflow edge.

Within the outlet pipe 9c, the static mixer is in this case formed as a fixed worm coil 11c, which if appropriate may be provided with individual pins 27 over its circumference or length in order to improve the mixing action. However, the bottom end of the outlet pipe 9c now opens out into a transfer vessel 10c which collects the alloy suspension and can be docked or is fixed docked onto the filling hole 8 in the manner indicated. The transfer vessel

10c is advantageously once again provided with a discharge means or the plunger 26. As can be seen and as is indicated, it is once again advantageous for the vessel 10c to be provided with heating means X, if appropriate also with a cooling means O.

The embodiment in Fig. 5 is similar to that shown in Fig. 4 to the extent that in this case too a static screw coil 11c is fitted. This embodiment merely illustrates that it would be conceivable for the outlet pipe 9d to be held rotatably in bearings 29 on a base 29′ and to be driven, for example, by means of an externally fitted toothed ring 30 and a motor pinion 30 of a motor M1. Depending on the dimensions selected, in particular the length of the outlet pipe 9d, the direction of rotation may be either in the conveying direction of the metal flowing down under the force of gravity or advantageously in the opposite direction. In the case of the opposite direction to the conveying direction defined by the coil 11c, the metal remains in the region of the temperature-control means X and/or O of the outlet pipe 9d for longer, i.e. this pipe 9d can then if appropriate be made shorter. In addition, the gravity conveying in the downward direction of the outlet pipe 9d and the simultaneous rotation of this pipe in the opposite direction result in improved mixing. Nevertheless, this embodiment is not preferred in all cases, on account of the additional drive which has to be provided.

Fig. 6 illustrates a further embodiment in a sectional view from above, approximately on line VI-VI from Fig. 4. In this embodiment, an outlet pipe 9e, which is connected to the isothermal collection vessel 10c, includes, as suspending section, a series of cooling fins 31 which, in order to achieve a mixing action, can, although do not have to, be provided with diverter means, for example at 32, and/or with interruptions 33 and/or thickened diverter sections 34. It would also be possible for a diverter pin, for example similar to the pins 27 shown in Fig. 4 or in the style of Fig. 9 described below, to be provided in the channel between two such fins 31, in the region of an interruption, so that at least the streams of metal which have been split by the cooling fins flow back into one another or are backed up and then mixed with incoming metal.

Fig. 7 shows a section approximately on line VII-VII from Fig. 6, in which fins 31 and 31a are provided offset with respect to one another. It is clearly apparent that the fins 31a are also provided with cooling passages O. At this point, it should be mentioned that fins which are parallel to one another (as can be seen in the sectional illustration presented in Fig. 7), i.e. which do not per se result in any static mixing effect (apart from the turbulence of the layers which has been described with reference to Fig. 1A), are able to make a contribution to improving the cooling capacity, and consequently internals 31, 31a of this type are advantageous

with a view to increasing the size of the cooling surfaces. Therefore, it is conceivable to take account of differing cooling requirements for different alloys and/or solids contents by replacing different sizes of the cooling surface. For this purpose, the design which has been described above with reference to the exchangeable plate 19 is once again advantageous. However, if desired it would also be possible to provide an exchangeable inner pipe instead of an exchangeable plate 19.

A particular embodiment is to be shown with reference to Figs. 8, 8A and 9, from which it can first of all be seen that the outlet pipe 9f is running at an ever steeper gradient, i.e. at a steeper angle to the horizontal, from the top downward. This takes account of the fact that the metal becomes increasingly viscous as it cools and therefore may start to flow more slowly. The profile of the center line L' illustrated preferably approximately corresponds to a brachistochrone (cycloid), but other profiles, for example with straight sections which in each case adjoin one another at an angle, which may be comparable, for example, to a cycloidal profile, are also conceivable.

Furthermore, these figures provide a more pronounced illustration of something which has already been indicated in the embodiment shown in Fig. 3, namely a different temperature control in different regions. In the case shown in Fig. 8, this is so advanced that the outlet pipe 9f is

divided into individual rings 9.1 to 9.5 which can be fitted together and each have separate temperature-control circuits (only the cooling circuits are illustrated).

Therefore, there is a feed manifold pipe 35 and a discharge manifold pipe 36 provided along the outlet pipe 9f, both of which can be connected, via an associated connection piece 37 or 38, respectively, to corresponding feed lines and discharge lines. In each case one feed branch 39 at the upper end of each ring and one discharge branch 40 with a control valve V at the lower end of each ring 9.1 to 9.5 extend from these manifold pipes 35, 36 to each of the rings 9.1 to 9.5. Instead of being provided in the discharge branch 40, the control valve V could also be provided in the respective feed branch 39. Each ring 9.1 to 9.5 is assigned a temperature sensor 41, which in this case is shown in the drawing at the top side but preferably tends to lie in the region of the discharge branch.

The sensors 41 may for example - as is known from sensor cables - be connected to a bus 42 and they are interrogated on an ongoing basis by a processor 43 about the temperature which they measure. By way of example, each sensor 41 has an addressing part with a dedicated address and, after this address has been called up by the processor 43, transfers its temperature data to the latter. Then, after comparison with a SET value, the processor 43 can emit a corresponding control signal to the respectively associated

control valve V to which it is connected via a further bus 44 (or via individual lines). Of course, in the case of a bus 44, it must be possible also to address each control valve V. In accordance with the statement which has already been made, the SET values will substantially decrease, either linearly or slightly degressively, from 9.5 to 9.1. This means that with a degressive temperature gradient profile from the top downward, the temperature at the mouth or underside of the outlet pipe 9f will be higher than if the temperature were to be reduced linearly from ring to ring. To ensure optimum cooling, it may be expedient if in each case screw-like coils 48, which lead from the feed branch 39 to the discharge branch 40, are fitted in a lateral space 45 (cf. Fig. 8A) in each ring 9.1 to 9.5.

In this case, the static mixer is provided by pins 27a which are offset with respect to one another, if appropriate may be mixed with one of the embodiments described above and may - as illustrated - be arranged only at the base of the outlet pipe 9f or may alternatively also be distributed over the circumference.

Fig. 8A shows how the individual rings 9.1, 9.2 can be fitted together. To prevent metal from penetrating into the gap between two rings, in each case the upper ring 9.2 has an inner, downwardly directed skirt part 47 which covers the separating gap 47. It is then possible for a seal 48, e.g. made from impregnated ceramic fibers, to be provided in

corresponding grooves in the two rings 9.1, 9.2 in the parting gap 46 itself, which for this purpose faces in the axial direction rather than transversely to it, and this seal already contributes to securely holding the two rings together. A similar arrangement may also be provided at the outer side, with an upwardly directed skirt part 49 in each case on the lower ring 9.1, and a seal 50. Of course, this type of seal is only an example which can be modified as desired within the scope of specialist knowledge in the field of seals and insulations. An insulation which effects thermal decoupling between the individual rings is advantageous. To ensure that they are held together, each ring 9.1, 9.2 may have securing lugs 51 (preferably - as shown in Fig. 9 - on opposite sides of the rings) for a securing bolt 52 to be fitted through. Since it will be advantageous to form the outlet pipe or the rings from ceramic, it is expedient for the securing lugs 51 to bear flat against one another in the manner shown in Fig. 8A, in order to avoid bending moments, in which case the plug connection with the seals 48, 50 is in any case substantially free of tensile forces on account of the screw connection 51, 52.

A few examples are intended to explain the core of the invention further in the text which follows.

Example 1:

A first series of tests was intended to investigate

how, for a given setting of a specific metering weight, the inclination of the channel affects the temperature of a suspension comprising the Mg alloy AZ 91 downstream of the channel. A metering weight of 1260 g (constant pump capacity of approx. 50 cm^3/s and pumping duration of approx. 15 s) was set and a suspending section of a similar design to Fig. 4 was used. Instead of the forming machine, a thick-walled steel vessel (collection vessel) modeled on the shot sleeve of a die-casting machine was used as transfer vessel 10, from the center of which the sampling, which is yet to be described, took place. Instead of the discharge plunger 26, a cover was fitted onto the transfer vessel 10, through which two thermocouples had been led in order to record the suspension temperatures. The entire surface of the Mg was covered with shielding gas. It was known from preliminary tests that the transfer vessel 10 should be set to approximately 585°C in order in practice to provide the isothermal conditions desired. The suspension was removed from the transfer vessel 10 35 s after the metering pump 17 had been switched on, which corresponds to a die-casting machine cycle time which is quite sufficient for the metered quantity. The values determined are given in Table 1.

Table 1

Test No.	Melt temp. [°C] in the furnace (9)	Inclination °	Removal temperature [°C] after 40 s	Max. temp. diff. [K] between center and edge
1	630	15	585	4
2	632	15	586	4
3	630	10	584	3
4	631	10	584	3
5	630	10	583	3

The influence of the inclination of the suspending section 9, which had been varied within certain limits, on the temperature distribution in the suspension is therefore slight. The fluctuations in the temperature gradient in the transfer vessel 10 (right-hand column) are correspondingly slight.

To investigate the expected microstructure following a forming operation, a cylindrical specimen was punched out, removed and quenched immediately after the collection vessel had been filled in each test. The microsections which were then produced did not reveal any dendrites at all. The mean grain size of the predominantly globular microstructure was 100 µm.

Example 2:

A second series of tests was intended to investigate how the temperature conditions in the transfer vessel 10 alter when the dissipation of heat in the suspending section takes place via different forms of flow paths. The intention was to demonstrate that the dissipation of heat can be increased in order not to excessively lengthen the cycle time of a downstream die-casting machine despite the increasing metering weight.

For this purpose, in each test the same metering quantity of approximately 2200 g of the Mg alloy AZ 91 was used. Firstly, in two tests the cooling took place on the suspending section 9 as in Example 1 (15° inclination, same coolant temperature) to the target temperature by increasing the pumping time (from 15 s to 30 s; heat extraction 1); secondly, in two further tests, the cooling took place on the suspending section by increasing the dissipation of heat while keeping the original pumping time of 15 s (heat extraction 2). The increased dissipation of heat was substantially achieved by widening the suspending section and increasing the throughput of coolant. The results of the total of two times two tests are compiled in Table 2:

Table 2

Test No.	Melt temp. [°C] in the furnace (9)	Type of heat extraction (cf. text)	Pumping time [s]	Removal temperature [°C] after 40 s	Max. temp. diff. [K] between center and edge
6	635	1	30	589	4
7	635	1	30	590	4
8	634	2	15	588	4
9	634	2	15	589	4

The temperature deviations in the transfer vessel given in the last column are identical. The reason for the slight increase compared to Example 1 could be that the transfer vessel, as before, had been held at 585°C. These tests were also repeated with aluminum alloys, and a similar pattern emerged.

The example illustrates that by selecting a suitable suspending section 9 it is possible to substantially adapt to the cycle time of a die-casting machine (or other forming device) and to the required metering weights.

As in Example 1, specimens were produced. The microsections which were then made once again did not reveal any dendrites. The mean grain size of the predominantly

globular microstructure was likewise 100 µm.

Example 3:

The intention of this example was to investigate the influence of the residence time in the transfer vessel and the influence of the temperature in the transfer vessel on the microstructure. The tests were carried out using an Mg alloy which contained only 6% of aluminum and correspondingly had a reduced solidification interval compared to the alloy used in Examples 1 and 2. The temperature of the transfer vessel 10 was preset to 570°C and the alloy was cooled along the suspending section as in tests 8 and 9. The results are compiled in Table 3 below.

Table 3

Test No.	Melt temp. [°C] in the furnace (9)	Time [s] between start of metering and removal from the transfer vessel	Removal temperature [°C]	Max. temp. diff. [K] between center and edge	Temp. diff. [K] between center and edge at the time of removal
10	635	80	580	8	3
11	635	100	576	8	2
12	634	140	575	7	1
13	634	180	573	7	1

After removal of the suspension, it was tested at two points (center and edge). Although no dendrites were found, it was clearly apparent that eutectic inclusions were noticeable in particular in the edge zones. With increasing residence time in the transfer vessel, a tendency to form larger crystals was also found. Nevertheless, it can be concluded from this example that it is desirable but not particularly critical to maintain isothermal conditions in the transfer vessel 10. Slight temperature losses in the vessel do not cause any significant changes in the microstructure. However, prolonged actions of a relatively

major temperature gradient should be avoided, since this can lead to significant constitutional supercooling.

In all tests (Mg and Al), the typical thixotropic behavior was found, namely it was found that a certain contiguity (skeleton formation between the globules) ensured the dimensional stability of the alloy discharged from the collection vessel, e.g. in the form of a metal billet, but it was easy to deform the material under the action of shear forces.

PATENT CLAIMS

1. Process for providing a partially solidified alloy suspension having a desired solid and liquid phase content, in which the alloy is initially present in liquid form and is then cooled, for example along a suspending section (9), for a residence time in order to be fed to a forming means, in particular a cyclically operated forming means, characterized by the fact that the solidification parameters comprising residence time, extraction of heat and nucleation accordingly satisfy at least one of the following conditions:

a) the residence time over the suspending section (9), which is preferably inclined at an angle other than 90°, is selected in such a manner that the desired phase content is achieved over the suspending section (9) at least approximately within the cycle time of the forming machine;

b) at least 20% of the melt heat, given in enthalpy values in kJ/mol, is extracted from the liquid alloy along the suspending section (9), which is preferably inclined at an angle other than 90°;

c) the liquid alloy - initially after a first number of nuclei have been distributed in a melting volume - is fed continuously to a second step as an additional nucleation step in a turbulent flow with extraction of heat, and the partially solidified alloy suspension obtained in this way is passed to the forming means (1, 16, 20) in a third step.

2. The method as claimed in claim 1, characterized by the fact that at least one of the following features is carried out:

A) at most 60% of the melt heat, given in enthalpy values in kJ/mol, preferably 30% to 50% of the melt heat, is extracted from the liquid alloy along the suspending section (9);

B) the suspending section (9) is cooled using oil as coolant;

C) the melt is initially brought to a temperature which is no higher than 30°C, preferably no higher than 20°C, e.g. to a temperature which is approximately 10°C, above the liquidus temperature;

D) in the first step, the melt is initially brought to a temperature which is higher, for example by at least 50°C or more, than the liquidus temperature and is then brought to a temperature which is lower but is still above the liquidus temperature;

E) the third step leading to the forming means (1, 16, 20) is performed via a transfer vessel (10) which is filled directly from the suspending section;

F) the partially solidified alloy suspension obtained is fed to a cyclically or continuously operating continuous casting means;

G) the metal is a nonferrous metal, in particular a light metal;

H) during the processing of the melt, vibration energy, in particular ultrasound energy, is applied.

3. The process as claimed in claim 1 or 2, characterized by the fact that feature a) and/or b) additionally includes the following:

in the suspending section, the liquid metal passes through a static mixer (11), in which substantially a sufficient number of crystallization nuclei to prevent dendrite growth are formed, preferably by the temperature being cooled and homogenized through the volume of the metal by static mixing.

4. The process as claimed in one of the preceding claims, characterized by the fact that feature c) is carried out under at least one of the following conditions:

A) the first distributing step is carried out in an at least periodically continuously operating conveyor means (17) for the melt which is liquid and has been provided with a first number of nuclei;

B) a turbulent flow is generated by the further nucleation step in a suspending section (9) for the alloy suspension and is conveyed along by the force of gravity;

C) a turbulent flow is generated by the further nucleation step in a suspending section (9) for the alloy suspension, the extraction of heat and the nucleation taking place at internal fittings (11, 17a) during the conveying step upstream of and/or along the suspending section (9);

D) the extraction of heat takes place at a component (17A) of a conveying means (17) for conveying the melt to the second step, the extraction of heat preferably taking place at a conveying shaft (17A) of the conveying means (17).

5. The method as claimed in one of the preceding claims, characterized by the fact that part of the operation is carried out under oxidation-resistant conditions, the oxidation-resistant conditions preferably being established by means of a shielding gas which is supplied in particular as a coolant at a correspondingly lower temperature than the alloy suspension, for example in liquid form, and by the fact that preferably for the purpose of preventing oxidation the melt or the alloy suspension is passed into substantially closed spaces.

6. A device for carrying out the process as claimed in one of the preceding claims, having a reservoir (9') for liquid alloy and a downstream suspending section (9) which extends from an entry to an exit, characterized by the fact that a distributing and conveying means (17) for at least periodically continuously conveying a volume of melt across the suspending section (9) is provided in the reservoir (9').

7. The device as claimed in claim 6, characterized by the fact that the reservoir (9') satisfies at least one of the following conditions:

A) it is formed as a heatable furnace chamber which preferably includes at least two sections in which different

temperatures can be produced;

B) it can be moved to different levels by means of a lifting device (57).

8. The device as claimed in claim 6 or 7, characterized by the fact that the distributing and conveying means is formed as a screw or propeller pump (17) which is preferably equipped with at least one of the following features:

A) a drive (M) which can be switched on and off over the cycle time for conveying purposes is assigned to it;

B) a variable-speed drive (M, C) is assigned to it;

C) the screw or propeller pump (17) has a hollow shaft (17a) which is cooled by a cooling medium;

D) the screw or propeller pump (17) extends into the reservoir (9') from above and conveys the melt to a pouring arrangement (26, 9) located above it;

E) the screw or propeller pump (17) projects into the reservoir (9') and has its entry above the base of the reservoir.

9. The device as claimed in one of claims 6 to 8, characterized by the fact that the suspending section has at least one of the following features:

A) the suspending section (9) is assigned at least one cooling means (O), the cooling means (O) preferably being divided into at least two successive sections which can be cooled independently of one another (Fig. 3, 8);

B) the suspending section (9; 10) is assigned at least

one heater means (X), which is preferably divided into at least two, in particular successive sections which can be heated independently of one another (Fig. 1, 3, 8) and/or which is assigned at least one temperature control means;

C) the suspending section (9) is inclined downward from its entry to its exit, the inclination (α) of the suspending section (9) preferably being adjustable;

D) the inclination of the suspending section (9f) becomes steeper toward the exit;

E) it is accommodated in a closed pipe;

F) it has at least one releasably secured base wall (19);

G) at its flow surface, it has internals (11) which increase in size over the length and are preferably formed at least in part as a static mixer;

H) it is arranged between the inlet and the outlet of a pouring means of a reservoir (9') for the liquid alloy, the pouring means (9) preferably being the outlet pipe of a melting furnace (9');

I) at its exit, it is provided with a closure means (18);

J) it is connected upstream of a forming machine (1; 18; 20), for example a die-casting machine (1) or a continuous-casting device;

K) downstream of it there is a transfer vessel (10), which is preferably provided with a heater means (X) and/or a

cooling means (O);

L) a vibration generator, preferably a high-frequency vibration generator, in particular an ultrasound means, is connected to the suspending section or in a connected part (10).

10. A device having a reservoir for liquid alloy and a downstream suspending section (9), in particular for carrying out the process as claimed in one of claims 1 to 5, characterized by the fact that the suspending section (9) has at least one melt-guiding surface, or at least a base (19) which extends along the length, and this surface or base (19) is made at least in part from a material which cannot be wetted by the alloy suspension, and by the fact that preferably at least one of the following features is provided:

A) the unwettable material includes a ceramic material, preferably silicon nitride and/or titanium boride;

B) the surface (19) comprising the unwettable material is exchangeably connected to a supporting part of the suspending section (9).

11. A continuous-casting device for carrying out the process as claimed in one of claims 1 to 5, characterized by the fact that upstream of it there is a metering pump (17) which, for metering purposes, has a setting arrangement (25, 26) for setting a predetermined level, which metering pump (17) is preferably arranged in a chamber of a metering

furnace (9') and expediently has a pump tube (17'') which extends down into the melt as far as a certain level which is located between the base region and the predetermined level.

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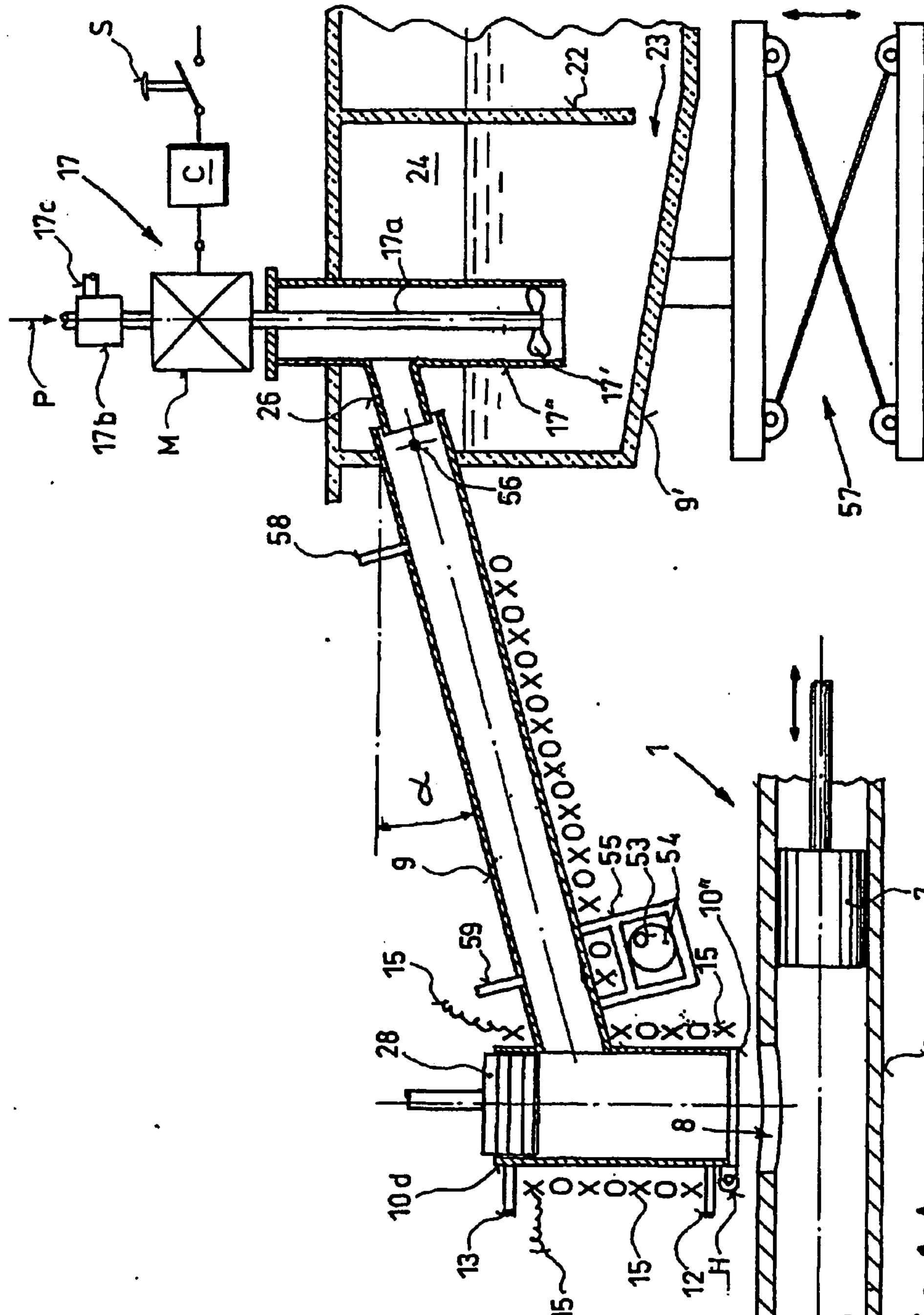

Fig.1 A

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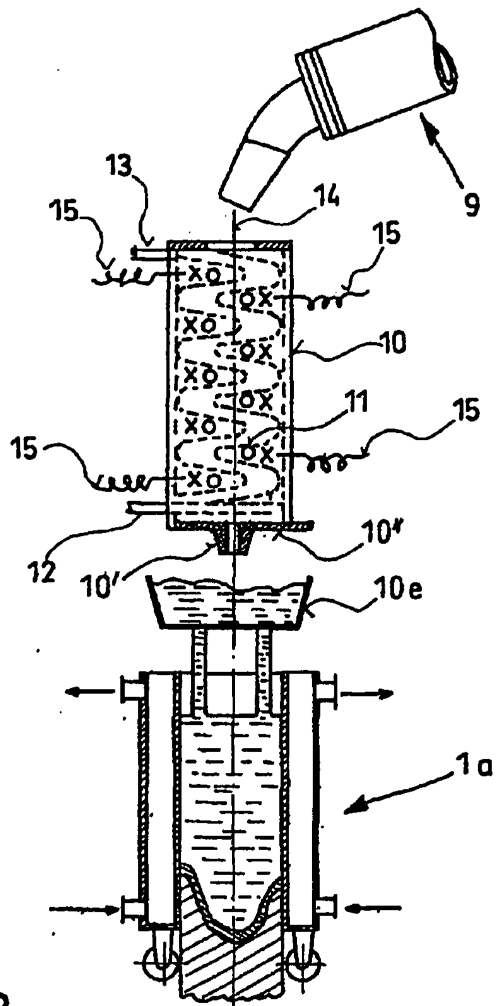

Fig.1B

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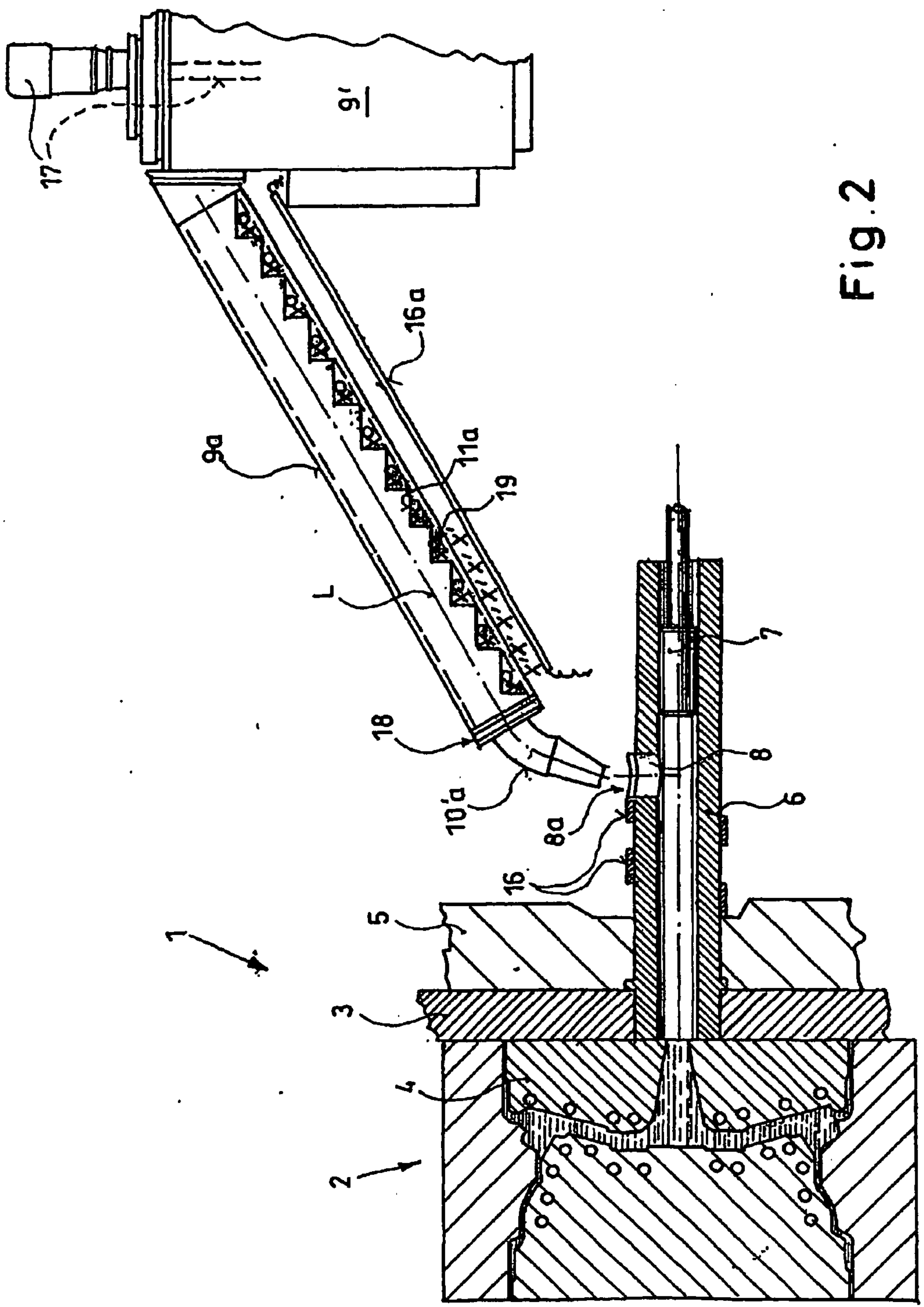

Fig.2

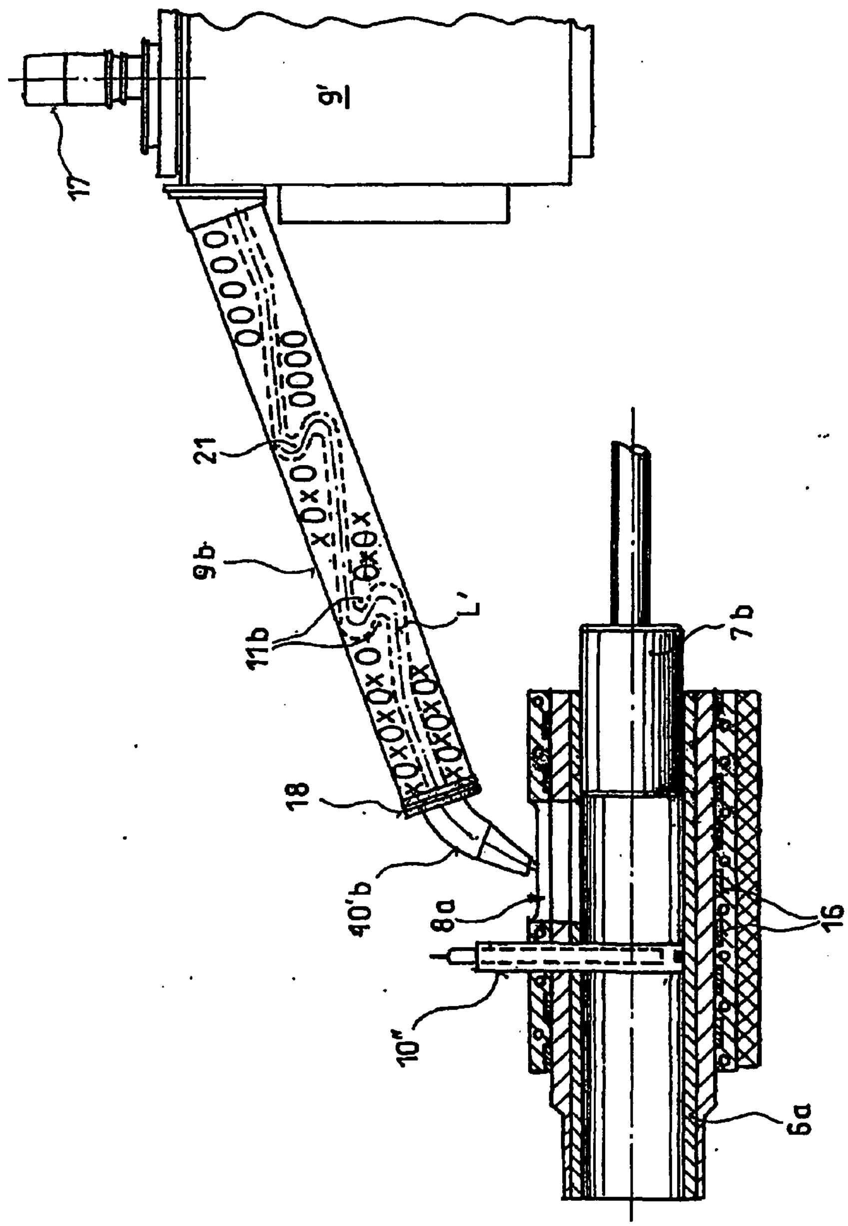

Fig. 3

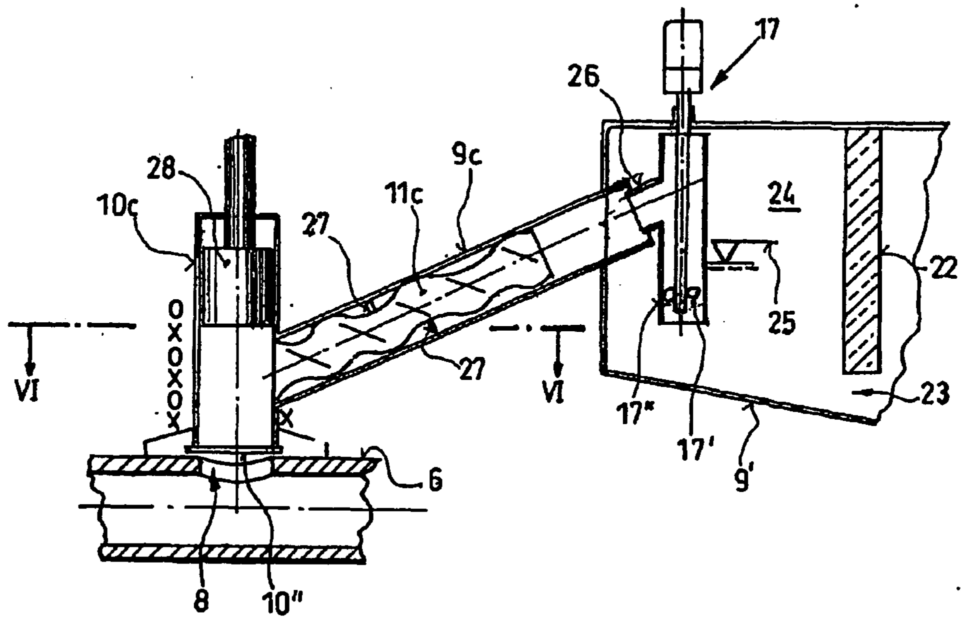
17
26
24
28
10c
9c
11c
27
22
25
VI
27
VI
23
17"
17'
9'
6
8
10"

Fig. 4

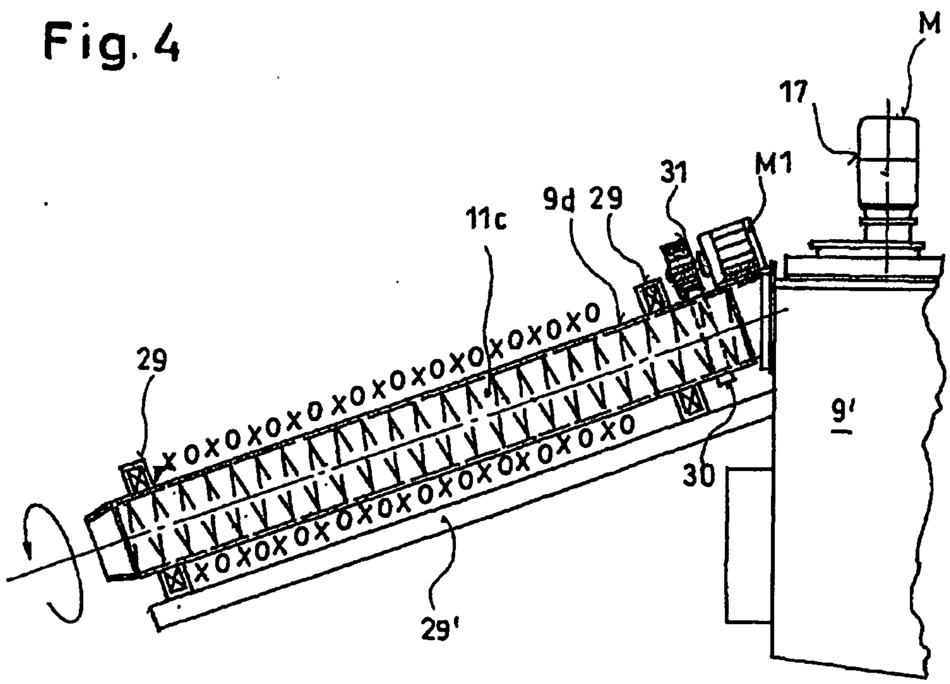
M
17
31
M1
9d
29
11c
29
9'
30
29'

Fig. 5

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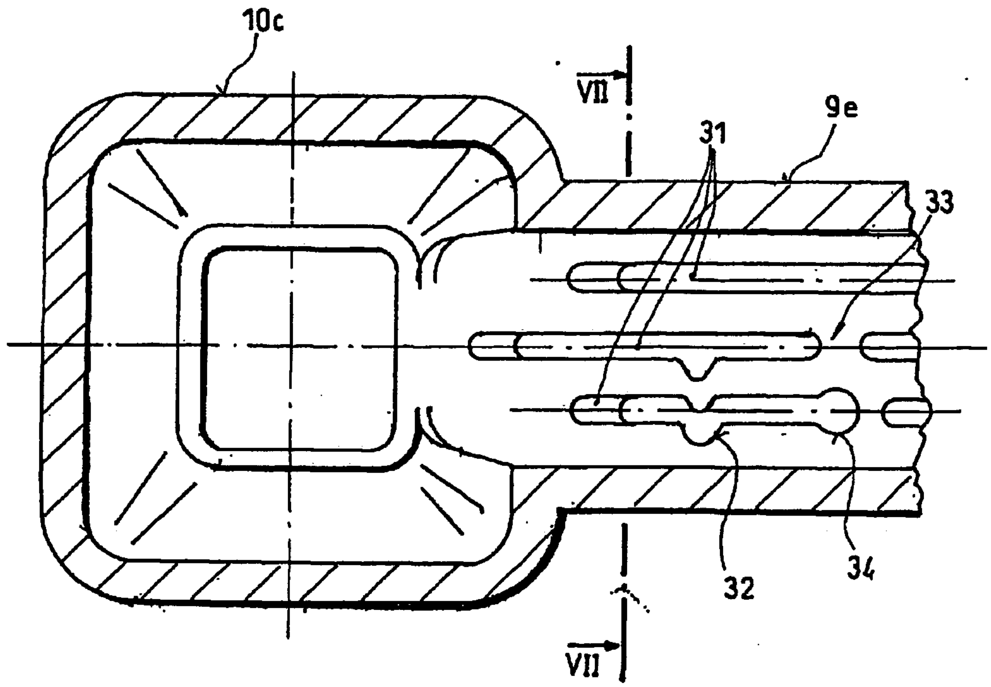

Fig.6

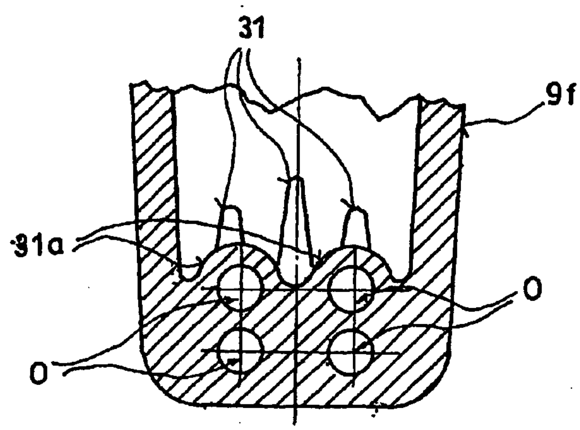

Fig.7

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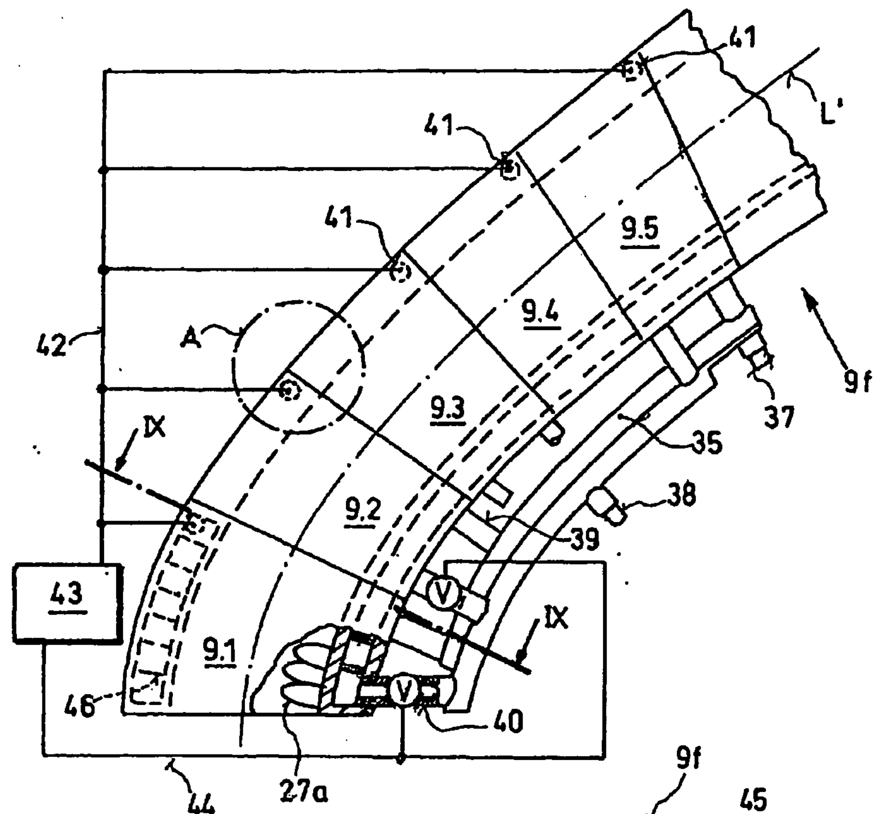

Fig. 8

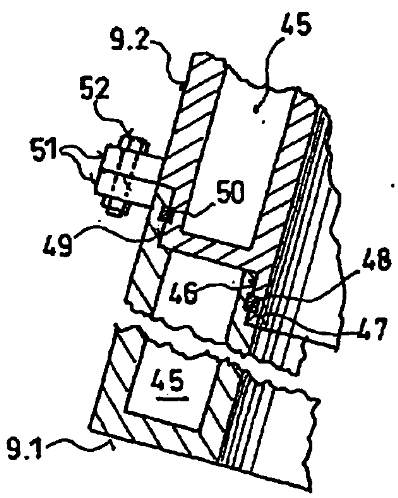

Fig. 8A

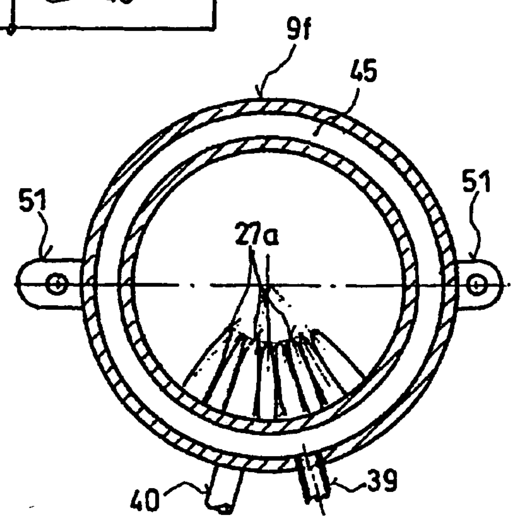

Fig. 9